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(54) Non-peroxide trivalent chromium passivation

(57) An aqueous acidic peroxide-free solution for treating receptive metal surfaces to impart a chromium passivate film thereon contains trivalent chromium ions, hydrogen ions to provide a pH of 1.2 to 2.5, nitrate ions as the essential oxidizing agent to activate the hydrated trivalent chromium to form a chromate film on the substrate, and iron, cobalt, nickel, molybdenum, manganese, aluminium, lanthanum and/or cerium ions to activate the formation of the chromate passivate film. The use of peroxide as an oxidizing agent is avoided, as are its accompanying problems such as high consumption of oxidizing agent and rapid loss. The aqueous acidic solution can also contain sulphate ions, halide ions, organic carboxylic acid, a silicate compound, and a wetting agent.

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SPECIFICATION

Non-peroxide trivalent chromium passivation

5 Aqueous acidic chromium passivating solutions are in widespread commercial use for improving the corrosion resistance and for enhancing the appearance of various receptive metal surfaces including zinc, zinc alloy, cadmium, cadmium alloy surfaces and the like. Such passivating solutions can be controlled to impart a yellow or a blue-bright coating to the surface in which the latter simulates a chromium finish. Such chromium passivate solutions conventionally contained chromium ions in the hexavalent state but 10 in more recent years have been replaced by trivalent chromium ions in view of the increased simplicity and efficiency in treating waste effluents containing chromium in the trivalent state. While initially, trivalent chromium passivate solutions were less effective than the conventional hexavalent chromium passivating compositions, further research and development has now produced trivalent chromium passivate compositions which provide for acceptable passive films on a variety of receptive metal substrates. Typical 15 of such processes are those described in United States Patents No. 4,359,345; 4,359,346; 4,359,347; 4,359,348; 4,349,392; and 4,367,099 which are all assigned to the present applicant and the teachings of which are incorporated herein by reference to the extent that the disclosures contained therein are relevant to the subject matter of the present invention. Typical other prior art compositions and processes for treating zinc and zinc alloy surfaces are those such as disclosed in United States Patents No. 2,393,663; 2,559,878; 20 3,090,710; 3,553,034; 3,755,018; 3,795,549; 3,843,430; 3,880,772; 3,932,198; 4,126,490; 4,171,231; 4,263,059; British Patent Nos. 586,517 and 1,461,244; and German Patent No. 2,526,832.

Chromium passivate compositions of the types commercially employed and as described in the aforementioned patents invariably employ peroxide-type oxidizing agents, particularly hydrogen peroxide, which is a necessary bath constituent to produce acceptable passive films. A continuing problem 25 associated with such peroxide-type passivating compositions is the high rate of consumption and relatively rapid loss of the peroxide oxidizing agent necessitating frequent replenishment and a further careful control by pH by adjustment due to the relatively rapid rise in pH. The consumption of peroxide is due in part to the presence of various activating metal ions present in the solution as well as contaminating metal ions such as zinc, cadmium and iron, for example, which are introduced by the dissolution of the metal from the 30 substrates being treated which tend to catalyze a decomposition of the oxidizing agent. The frequent replenishment of the hydrogen peroxide is not only time consuming but is also relatively costly. Such depletion of the peroxide oxidizing agent also occurs when the bath stands overnight end over weekends between operating shifts.

The advent of high-speed treatment of metal surfaces such as zinc, for example, in which the aqueous 35 acidic chromium passivating solution is spray applied to the metal surface for short periods of time such as 1 to 10 seconds has further aggravated the problem due to the increased loss of the peroxide constituent in such spray applications and the volatilization and contamination of the surrounding atmosphere providing an environmentally objectionable working condition. High-speed immersion type applications in which jets of the passive solution are directed against the surface to be treated also result in an excessive loss of the 40 peroxide-type oxidizing agent.

It has also been observed in the processing of work pieces incorporating apertures which have not received a coating or plating of metal such as zinc, for example, of which metal tubing is typical, an immersion of such tubing into a peroxide-type chromium passivate solution causes a rapid flash-rusting of the interior of the tubing in a matter of only several seconds causing rust spots and further causing an 45 excessive consumption of the peroxide oxidizing agent during its reaction with the exposed ferrous metal on the interior of the tubing.

The present invention overcomes many of the disadvantages and problems associated with prior art 50 trivalent-type chromium passivating solutions employing an alternative non-peroxide oxidizing agent which is of relatively low volatility, is inexpensive, does not form environmentally objectionable vapours, can be employed in high-speed passivating processes without objectionable loss of the oxidizing agent, can be employed for passivating work pieces having exposed bare iron or steel surfaces such as tubing wherein the solution itself serves to passivate rather than flash oxidize such bare surfaces, and wherein the composition and the process of use of the composition is of simple and economical operation and control.

The invention broadly provides a peroxide-free chromium passivate film forming solution including an 55 oxidizing amount of nitrate ions.

The benefits and advantages of the present invention are achieved in particular by an aqueous acidic 60 chromium passivating solution comprising chromium ions substantially all of which are present in the trivalent state at a concentration ranging from about 0.05 grams per litre (g/l) up to saturation, hydrogen ions to provide an operating solution pH of about 1.2 to about 2.5, nitrate ions as the essential oxidizing agent present in an amount effective to activate the hydrated trivalent chromium to form a chromate passive film on the metal substrate being treated, and at least one additional metal ion selected from iron, cobalt, nickel, molybdenum, manganese, aluminium, lanthanum, cerium and lanthanide mixtures present in an amount effective to activate the bath and formation of a chromium passive film of the desired appearance on the substrate treated. The solution may optionally, and preferably, contain halide ions for imparting additional 65 hardness to the coating, a bath soluble and compatible silicate compound present in an

amount effective to impart increased corrosion resistance and hardness to the passivate film, a bath soluble and compatible organic carboxylic acid present in an amount effective to impart initial hardness and clarity to the passivate film as well as a wetting agent such as Biancol N from GAF Corporation comprising a condensate of an alkyl naphthalene sulphonate and formaldehyde. In addition, Dequest 2010, a phosphonate 5 from Monsanto, has been found advantageous for effecting clarification of the film when an aged bath has become contaminated with appreciable quantities of iron and zinc ions. The words 'Biancol' and 'Dequest' are trade marks.

In accordance with the process aspects of the present invention, a receptive metal substrate is contacted with an aqueous acidic treating solution of the foregoing composition, at a temperature ranging for example 10 from about 40° to about 150°F (4.4° to 66°C), preferably from about 70° to about 90°F (21°C to 32°C) for a period of time typically ranging from as little as 1 second up to about 1 minute or longer to form the desired passivate coating thereon. The passivated substrate can be directly dried after extraction from the bath or, optionally, can be subjected to a final rinse, preferably after an intervening water rinse, in a dilute aqueous silicate solution usually at a temperature of about 50° to about 150° (10° to 66°C) for a period of time usually 15 ranging from about 1 second up to about 1 minute or more in order to further enhance the properties of the film whereafter the surfaces are air dried.

Additional benefits and advantages of the present invention will become apparent upon a reading of the following description of the preferred embodiments taken in conjunction with the specific examples provided.

20 The present invention is particularly applicable, but not necessarily restricted to the treatment of cyanide and alkaline and acidic non-cyanide zinc electrodeposits to impart improved corrosion resistance and a decorative appearance on the treated substrate. Particularly satisfactory results are obtained on decorative zinc electrodeposits of a bright and semi-bright type although beneficial effects are also attained on zinc alloy substrates such as galvanized substrates, zinc die castings and substrates comprised of cadmium or 25 alloys of cadmium consisting predominantly of cadmium. It has also been observed that beneficial results are also obtained in the treatment of aluminium, aluminium alloy, magnesium and magnesium alloy surfaces to form a passivate film or coating thereon. Beneficial results have also been observed in the treatment of work pieces having exposed ferrous surfaces such as steel, for example, in which a passivation of such exposed surfaces is also attained simultaneously with the treatment of the coated or plated surfaces 30 such as zinc. Accordingly, the present invention in its broad sense is directed to the treatment of metal surfaces which are receptive to the formation of a passivate film thereon when contacted with the aqueous acidic solution of the present invention applied in accordance with the process parameters hereinafter disclosed.

A treating solution in accordance with the composition aspects of the present invention contains as its 35 essential constituents, chromium ions which are present substantially all in the trivalent state, hydrogen ions to provide a pH of from about 1.2 to about 2.5, nitrate ions as the essential oxidizing agent present in an amount effective to activate the hydrated trivalent chromium to form a chromate film on the metal surface being treated, at least one additional metal ion selected from iron, cobalt, nickel, molybdenum, manganese, aluminium, lanthanum, cerium and lanthanide mixtures of rare earth metals, (or a mixture thereof) present 40 in an amount effective to impart integral hardness to the galvanic chromate film and optionally, but preferably, sulphate ions, halide ions, or more compatible wetting agents, a bath soluble and compatible silicate compound, as well as bath soluble and compatible organic carboxylic acids as a hardness imparter.

The trivalent chromium ions can be introduced in the form of any bath soluble and compatible salt such as 45 chromium sulphate, $\text{Cr}_2(\text{SO}_4)_3$, chromium alum $[\text{KCr}(\text{SO}_4)_2]$, chromium chloride $[\text{CrCl}_3]$, chromium bromide $[\text{CrBr}_3]$, chromium fluoride $[\text{CrF}_3]$, chromium nitrate $\text{Cr}(\text{NO}_3)_3$, or the like. The trivalent chromium ions can also be introduced by a reduction of a solution containing hexavalent chromium ions preferably using sulphur dioxide or bisulphite providing a mixture of trivalent chromium ions and sulphate compounds. A material of the foregoing type which has been found particularly satisfactory for use in accordance with the practice of the present invention is Chrometan available from British Chromium. The word 'Chrometan' is a 50 trade mark.

The concentration of the trivalent chromium ions in the treating solution may range from as low as about 0.05 g/l up to saturation, with concentrations of about 0.2 to about 4 g/l being preferred. Typically, the operating bath contains from about 0.5 to about 2 g/l trivalent chromium ions.

The treating bath contains hydrogen ions in a concentration to provide a pH of about 1.2 to about 2.5 with a 55 pH range of about 1.5 to about 1.8 being preferred for producing clear to light-blue passivate films. Acidification of the operating bath to within the desired pH range can be achieved by a variety of mineral acids and organic acids such as hydrochloric acid, formic acid, acetic acid, propionic acid, and the like. Preferably, pH adjustment is effected by employing nitric acid and/or sulphuric acid which simultaneously introduces the desirable nitrate ions and sulphate ions in the operating bath. It has been observed that the 60 presence of sulphate ions in the bath is beneficial in achieving the desired passivation of the substrate and is included in the bath by the addition sulphuric acid and/or alkali metal and ammonium sulphate salts as well as metal salts of the other bath constituents. Generally, sulphate ion concentrations ranging up to about 15 g/l can be employed with amounts of about 0.5 g/l to about 5 g/l being preferred.

A further essential ingredient of the bath comprises nitrate ions as the principal oxidizing agent which can 65 be introduced in the form of nitric acid, alkali metal or ammonium salts or indeed of salts of the metal ions

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present in the bath. Supplemental oxidizing agents can be incorporated in minor amounts if desired although nitrate ions by themselves are preferred. The nitrate ions can be present in the bath in concentrations of from about 0.5 g/l up to saturation with concentrations of about 5 to about 50 g/l being preferred. The particular range of concentration of nitrate ions will be dictated to some extent by the 5 concentration of trivalent ions present as well as the other bath constituents in further consideration of the process parameters employed in forming the passive film. In so-called "high-speed" processes, high concentrations of the active ingredients are required to effect the formation of an adequate passive film in relatively short time periods such as as low as 1 second up to about 10 seconds. In contrast, during conventional passivating processes, time periods of about 10 seconds up to about 1 minute or longer can be 10 employed whereby corresponding lower concentrations of the active constituents can be employed.

A further, highly preferred constituent in the bath comprises at least one additional metal ion selected from iron, cobalt, nickel, molybdenum, manganese, aluminium, lanthanum, cerium and lanthanide mixtures. The foregoing metal ions or mixtures of metal ions are conveniently introduced into the bath by way of bath soluble and compatible metal salts including the sulphate, nitrates, halide salts, or the like. For 15 economic reasons, the lanthanum ions when used are introduced not as pure lanthanum compound, but as a mixture of the rare earth salts of the metals of the lanthanide series (hereinafter designated as "lanthanide mixture") which contains lanthanum compounds as the predominant constituent. A commercially available lanthanide mixture which is suitable for use in the practice of the present invention is Lanthanum - Rare Earth Chloride, Product Code 5240, available from Molycorp, Inc. of White Plains, New York. This product has 20 the general formula $\text{La-REC}_1(\text{H}_2\text{O})$ and is available as a solution containing about 55 to 60 percent by weight solids. The solution is prepared from a rare earth oxide (REO) concentrate containing a minimum of 46 percent by weight total REO comprising about 60 percent lanthanum oxide (La_2O_3), 21.5 percent neodymium oxide (Nd_2O_3), 10 percent cerium oxide (Ce_2O_3), 7.5 percent praseodymium oxide (Pr_2O_{11}) and 1 percent of residual REO. The presence of such other rare earth metals in the solution does not appear to have 25 any adverse effect at the low concentrations on which they are present and may further contribute to the activation of the treating solution in forming the passive film.

The concentration of the additional metal ions may be kept within a range of about 0.02 up to about 1 g/l with concentrations from about 0.1 to about 0.2 g/l being preferred. While such metal ions can be used in concentrations above 1 g/l, such as, up to about 10 g/l, the use of such higher concentrations tends to 30 produce dull films of a yellow tint rather than the desired clear or light-blue films. For this reason, such higher concentrations are usually undesirable from an appearance standpoint.

As a further optional but preferred constituent, the bath contains halide ions including chloride, bromide and fluoride ions which have been found to enhance the hardness of the passive film on the treated substrate. The halide ions or mixture thereof can conveniently be introduced employing any of the alkali 35 metal and ammonium salts thereof as well as salts of the metal ions hereinabove set forth. The concentration of the total halide constituent in the bath normally may range up to about 2 g/l with concentrations of about 0.1 to about 0.5 g/l being typical.

Optionally, but preferably, the operating bath may contain bath soluble and compatible organic carboxylic acid or salt thereof of the structural formula:

40 $(\text{OH})_a\text{R}^A(\text{COOH})_b$ 40

wherein:

a is an integer from 0 to 6 (or up to the maximum permitted by the value of b and the entity represented by 45 R^A);

b is an integer from 1 to 3; and

R^A represents a $\text{C}_1\text{-}\text{C}_6$ alkyl or alkenyl group or a $\text{C}_6\text{-}\text{C}_{10}$ aryl group.

A bath soluble and compatible salt thereof may be used.

The bath soluble and compatible carboxylic acid or salt can be present in an amount effective to impart 50 increased clarity and initial hardness to the gelatinous chromate film deposited. The preferred concentration or range of concentrations of the clarity-hardness agent, if used, will depend proportionally on the molecular weight of the particular acid and/or metal salt employed, with higher concentrations required for an equivalent effectiveness as the molecular weight of the additive agent increases. The particular concentration to achieve optimum clarification and hardness is also dictated to some extent by the 55 concentration of the silicate and other metal ions present in the bath with higher concentrations being used as the metal ion concentrations increase. Generally, the organic carboxylic acid additive agent or metal salts thereof can be employed in amounts ranging up to about 4.0 g/l with concentrations of about 0.1 to about 1.0 g/l being typical.

The carboxylic acid and/or salt additive can be introduced as the organic acid itself or as any bath soluble 60 and compatible metal salt including the alkali metal salts, ammonium salts and salts of the several additional metal ions in the bath. For economic reasons, the organic acid is usually introduced as an acid or as the sodium or potassium salt thereof.

With the scope of the structural formula as hereinabove set forth, organic carboxylic acids which have been found particularly suitable include malonic, maleic, succinic, gluconic, tartaric and citric acids, of which 65 succinic acid has been found particularly effective, either in its free acid or salt form.

An optional but preferred constituent of the treating bath comprises a silicate compound present in an amount effective to provide an improved corrosion protection and hardness to the passivate film formed on the treated substrate. The silicate compound comprises a bath soluble and compatible inorganic or organic silicate compound as well as mixtures thereof which are present in an amount of about 0.01 up to about 5 g/l calculated as SiO_2 , with concentrations of about 0.1 to about 0.5 g/l being preferred. When inorganic silicates are employed, concentrations above about 2 g/l in the operating bath are undesirable because of the tendency of the silicate to form fine flocculent precipitates with the metal ions present in the bath under the acidic conditions present which contributes toward bath instability. Organic silicates, on the other hand, provide for improved bath stability and are preferred for the formation of make-up and replenishment 5 concentrates because of the improved stability and prolonged shelf life.

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Inorganic silicates suitable for use in the practice of the present invention include alkali metal and ammonium silicates of which sodium silicate ($\text{Na}_2\text{O}(\text{xSiO}_2)$ ($\text{x}=1-4$) and potassium silicate ($\text{K}_2\text{O}(\text{ySiO}_2)$ ($\text{y}=1-5$)) are preferred for economic reasons. Organic silicates which can also be satisfactorily employed include tetramethylammonium silicate, phenyltrimethylammonium silicate, disilicate and trisilicate, and 10 benzyltrimethylammonium silicate and disilicate. Such silicates meeting the purposes of this invention are expressed by the following general formula:

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20 wherein R represents a quaternary ammonium radical substituted with four organic groups independently selected from $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_1\text{-C}_6$ alkanol, $\text{C}_1\text{-C}_{10}$ aryl and $\text{C}_7\text{-C}_{18}$ alkylaryl, where R' represents R or a hydrogen atom, where x is a number from 1 to 3 and where y is a number from 0 to 15.

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Such water soluble organic silicates including their synthesis and characterization is more fully described in literature such as the article by Merrill and Spencer, "Some Quaternary Ammonium Silicates", published 25 in the Journal of Physical and Colloid Chemistry, 55, 187 (1951), the substance of which is incorporated herein by reference. Similar silicates including typical synthesis thereof is disclosed in U.S. Patent No. 3,993,548 to which reference is also made for further details.

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In addition to the foregoing, the use of a small effective amount of a variety of bath compatible wetting agents also provides beneficial results in the nature of the passivate film deposited. When employed the 30 wetting agent can be present in concentrations up to about 1 gram per litre (g/l) with concentrations of about 50 to about 100 mg/l being preferred. Wetting agents suitable for use in the treating bath include aliphatic fluorocarbon sulphonates available from 3M under the Fluorad brandname, such as, for example, Fluorad FC 98, which is a nonfoaming wetting agent and its use at about 100 mg/l in the working bath improves the color and hardness of the passivate film. A second class of suitable wetting agents is the sulpho derivatives of 35 succinates. An example of this class is Aerosol MA-80 which is a dihexyl ester of sodium sulphosuccinic acid and is commercially available from American Cyanimid Company. A third class of suitable wetting agents is the sulphonates of naphthalene which are linear alkyl naphthalene sulphonates, such as Petro Ba, for example, available from Petrochemical Company. "Petro Ba" is a trade name.

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Particularly beneficial results are achieved by employing polymeric-type wetting agents such as bath 40 soluble salts of sulphated alkylphenoxy poly (ethylene oxy ethanol) such as Alipal CO433, for example; sulphonated alkyl naphthalene, such as Nekal BX/8 as well as bath soluble and compatible salts of sulphonated naphthalene-formaldehyde condensates such as Biancol N. The use of controlled amounts up to about 1 g/l of 1-hydroxy ethylidene-1,1-diphosphonate (Dequest 2010) has been found particularly beneficial as a clarifying agent for the passivate film in aged operating baths containing appreciable concentrations of 45 contaminating zinc and iron ions, for example, introduced by the dissolution of zinc and iron surfaces of articles being treated. 'Alipal', 'Nekal', 'Biancol' and 'Dequest' are trade names.

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In accordance with the process aspects of the present invention a trivalent chromium operating bath as hereinbefore described is applied to a substrate by spray, immersion, flooding or the like for a period of time sufficient to form the desired passivate film thereon. The treating solution can be applied at a temperature 50 ranging from about 40° up to about 150°F (4.4° to 66°C), with temperatures ranging from about 70° to about 90°F (21° to 32°C being preferred. The contact time of the solution with the substrate can vary from as little as about 1 second to as long as 1 minute or longer. In conventional passivating processes, contact times in which the work is immersed in the aqueous acidic solution can range from about 10 seconds up to about 1 minute in consideration of the thickness of the film required, the amount of cleaning of the substrate 55 required and the speed of production of workpieces. The particular time of contact to achieve the desired passivate film is effected by the pH. Generally, a pH of about 1.5 normally requires about 10 to 20 seconds to prepare a passivate film of satisfactory colour and corrosion protection. On the other hand, a pH of about 2.5 requires a contact time of about 35 to about 50 seconds to accomplish a similar film.

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In a high-speed passivating processes, of the general types employed in the treatment of coil steel, wire 60 and tubing in a continuous process, passivation must be effected in a matter of few seconds in view of the high speed of travel of the work pieces through the passivation section. Typically, contact times of only about 1 up to about 10 seconds are commercially feasible and the aqueous solution is applied by spray or by jets under high velocity as well as by immersion to achieve uniform contact. In view of the shorter time period available, the concentration of the active constituents is increased to achieve a comparable passivate 65 film deposition within the shorter available time period.

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At the conclusion of the passivation treatment, the article is extracted and generally is dried such as by warm circulating air. It is also contemplated that the workpieces can be subjected to one or a plurality of water rinses to remove residual passivate solution from the surfaces thereof whereafter the substrates can be further contacted with a dilute post silicate rinse solution which may range from room temperature to an elevated temperature of up to about 150°F (66°C) for a period of about 1 second up to about 1 minute or longer. Such dilute silicate rinse solutions contain as their essential constituents, a bath soluble and compatible inorganic or organic silicate compound as well as mixtures thereof of the same type as previously described in connection with those suitable for use in the aqueous acidic passivating bath. The silicate compound can be present in an amount of about 1 up to about 40 g/l with amounts preferably ranging from about 5 to about 15 g/l calculated as SiO_2 . The post silicate rinsed substrate after removal from the rinse solution can be dried such as by recirculating warm air. 10

In order to further illustrate the present invention, the following examples are provided. It will be understood that the examples are provided for illustrative purposes and are not intended to be limiting of the scope of the present invention as herein described and as set forth in the claims. 15

Example 1 15

A trivalent chromium concentrate designated as "Concentrate A" is prepared by forming an aqueous solution containing 30 g/l trivalent chromium ions introduced as chromium sulphate, 30 g/l citric acid, 90 g/l sodium nitrate, 11 g/l nickel ions introduced as nickel sulphate and 30 g/l of a wetting agent comprising a polymeric alkyl naphthalene sulphonate from GAF designated as Blancol N. A second aqueous concentrate designated as "Concentrate B" is prepared by dissolving 600 g/l of sodium nitrate in water. 20

The foregoing concentrates are suitable for admixture with water to form operating baths in accordance with the following examples.

Example 2A 25

An operating bath suitable for use in the formation of a chromium passivate coating under general operating conditions including contact times ranging from about 10 up to about 60 seconds is prepared by admixing 0.5 percent by volume of Concentrate A and about 1 percent by volume of Concentrate B in water forming a series of test solutions. The pH of the operating solution is adjusted to about 1.5 employing nitric acid. The operating bath is contacted with non-cyanide bright acid zinc plated steel test panels at a temperature of 60° to 90°F (16° to 32°C) employing air agitation.

Example 2B 35

A bath similar to that of Example 2A is prepared by mixing 3 percent by volume of Concentrate A and 3 percent by volume of Concentrate B in water. The pH of the operating solution is adjusted to about 2.5 using nitric acid. The operating bath is contacted with non-cyanide bright acid zinc plated steel test panels at a temperature of 90°F (32°C) employing mechanical agitation.

Additionally, operating solutions of each of the foregoing compositions of Examples 2A and 2B are employed for passivating zinc plated fasteners in barrel plating apparatus, various rack plated zinc plated steel stampings and elongated zinc plated threaded rods under simulated commercial process conditions. 40

In each instance, the chromium passivate film is clear, hard and deep-blue in appearance.

It will be appreciated that the passivation treatment is normally performed in series following the zinc or other plating operation and the available time for the passivation treatment is determined to a large extent by the machine cycle and process sequence of the parts passing through the plating section of the process. 45

Accordingly, to achieve the desired cleaning of the parts prior to plating, to achieve the desired thickness of the electrodeposit on the part, variations will occur in the available time for the subsequent passivation treatment of the plated parts. This can be accommodated by adjusting the pH of the passivation solution to achieve proper colour and corrosion protection within the particular time frame available. For example, when contact times of from about 10 to 50 about 20 seconds are available, the passivating solution is preferably adjusted to a pH of about 1.5. When greater time periods of about 35 to about 50 seconds are available, a pH adjustment to about 2.5 will provide equivalent results. 50

Example 3A 55

An aqueous acidic passivate solution suitable for high-speed applications is prepared by admixing in water about 10 percent by volume Concentrate A and about 3 percent by volume Concentrate B as described in Example 1. A series of operating baths is prepared and the pH is adjusted with nitric acid to about 1.5. The passivating solution is controlled to a temperature of about 70°F (21°C).

Example 3B 60

An aqueous acidic passivate solution suitable for high-speed applications is prepared by admixing in water about 10 percent by volume concentrate A and about 10 percent by volume Concentrate B as described in Example 1. A series of operating baths is prepared and the pH is adjusted with nitric acid to about 2. The passivating solution is controlled to a temperature of about 90°F (32°C).

65 Solutions of the foregoing type are suitable for use under so-called high-speed conditions and are

employed in series with processes for electroplating steel coils, strips, wire and tubing in a continuous manner. Under such conditions, contact times of only about 1 to about 10 seconds are available to achieve an appropriate passivation treatment. The passivating solution can be applied by high pressure spray or by immersion of the strip or continuous article in the solution through which it passes rapidly from the inlet end 5 to the outlet end thereof.

Under the foregoing composition and operating parameters, zinc plated workpieces processed under simulated commercial high-speed operations were provided with a hard, clear, blue-bright passivate film.

Examples 4A to 4C

10 An aqueous acidic operating bath is prepared by forming an aqueous solution containing 2 percent by volume of Concentrate A and 3 percent by volume of Concentrate B as described in Example 1 which is controlled at a temperature of 75°F (24°C). The pH of the solution is adjusted at various levels employing nitric acid. Acid zinc plated test panels and work pieces are passivated employing the foregoing solution at different pH levels for different time periods employing conventional immersion processing with air 10

15 agitation as well as barrel treatment.

The resultant treated articles are subjected to a 5 percent salt spray test to white corrosion. From the foregoing tests, a pH of 1.5 and a treatment time of from about 10 to about 20 seconds (Example 4A) is found optimum for treating rack panels as well as barrel plated parts. A pH of about 1.7 to about 2 at a treatment time of about 15 to about 25 seconds (Example 4B) is found optimum under the foregoing composition and 20 processing parameters. At a pH of 2 to about 2.5, contact times of about 25 to about 40 seconds (Example 4C) provide optimum protection. In each instance, test panels which were rack treated had a 5 percent salt spray period ranging from 16 to 24 hours while barrel treated test pieces had a 5 percent salt spray resistance of from about 8 to about 16 hours.

25 *Examples 5A to 5D*

An aqueous acidic operating solution adapted for high-speed treatment of workpieces is prepared by forming an aqueous solution containing 10 percent by volume of Concentrate A and with varying amounts of Concentrate B ranging from about 2 up to about 10 percent by volume. The adjustment of pH to various levels is made by the addition of nitric acid.

30 Bright acid sulphate zinc plated steel test panels of a size 4 inches by 6 inches (10 cm x 15 cm) were treated with the passivating solutions under controlled difference pH conditions, treatment times, and various amounts of Concentrate B. The tests were conducted under conditions simulating the travel of zinc plated coil stock or zinc plated strip stock through a solution tank at a linear speed of about 150 to about 200 feet per minute (46 to 61 m/mm). This was achieved by employing a tank having a cell immersed therein

35 incorporating a nozzle arrangement to effect a downward flow of solution at a rate of about 26 US gallons per minute (95 litres/min) past a stationary panel supported within the cell. The treated test panels were subjected to a 5 percent salt spray test to white corrosion and the results under the particular processing conditions and concentrations employed are set forth in Table 1.

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TABLE 1

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	Example	pH	Treatment Time, Sec.	Conc. B Vol. %	Corrosion 5% Salt Spray, Hrs.	
45	5A	1.5	2-4	2-3	8-10	45
	5B	1.5	2-4	6-10	20-24	
	5C	1.8-2.0	5-10	2-3	8-10	
	5D	1.8-2.0	5-10	6-10	20-24	

50 *Examples 6A to 6D*

An operating solution is prepared by forming an aqueous solution containing 2 volume percent of Concentrate A and 3 volume percent of Concentrate B of Example 1 and adjusting the pH to about 2 employing nitric acid. The operating bath was divided into four separate samples and various amounts of iron ions in combination with 3 g/l of zinc ions were added to each sample to simulate an aged bath typical of

55 a commercial bath contaminated with such zinc and iron ions after prolonged use. Acid zinc plated test panels were immersed in each sample bath for a period of about 20 seconds and the resultant passivate film was observed. Two of the bath samples (Examples 6B and 6D) incorporated the clarity agent Dequest 2010 and the results as set forth in Table 2 evidence the benefit attained employing this additive agent in the presence of relatively high levels of iron contamination.

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TABLE 2

	Example	Fe Ions, ppm	Zn Ions, g/l	Desired g/l	Appearance	
5	6A	25-50	3	0	Acceptable blue	5
	6B	25-50	3	0.1-0.4	Acceptable blue	
	6C	150	3	0	Hazy, Cloudy	
	6D	150	3	0.1-0.4	Acceptable blue	
10	<i>Example 7</i>					10
	A dry powder concentrate is prepared containing 54 percent by weight chromium sulphate (Chrometan), 2 percent by weight of the wetting agent Alipal CO433, 3 percent by weight of the wetting agent Nekal BX78, 10 percent by weight citric acid, 20 percent by weight sodium metallosilicate and 10 percent by weight nickel sulphate hexahydrate.					
	A working solution is prepared by dissolving 15 g/l of the dry concentrate in water in addition to 50 g/l of sodium nitrate. The working solution is adjusted to a pH of about 1.7 to about 2 with nitric acid.					
15	Test panels which were plated in an acid chloride zinc plating bath, water rinsed are thereafter contacted with the working solution by immersion employing hand agitation for a period of 15 to 20 seconds. The panels are subsequently water rinsed and hot air dried. An inspection of the test panels evidences the formation of a clear, blue passivate film on the zinc surface similar to that observed in connection with prior Examples 2, 3 and 4.					
	While it will be apparent that the preferred embodiments of the invention disclosed are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope of fair meaning of the claims.					
20						20
25						25
	CLAIMS					
30	1. A peroxide-free trivalent chromium passivate film forming solution including an oxidizing amount of nitrate ions.					
	2. A solution as claimed in Claim 1, wherein the composition is an aqueous acidic solution.					
	3. A solution as claimed in Claims 1 or 2 including iron, cobalt, nickel, molybdenum, manganese, aluminium, cerium and/or lanthanum, ions.					
	4. A solution as claimed in Claim 3, wherein the lanthanum ions are provided by lanthanum mixture.					
35	5. A solution as claimed in any one of Claims 1 to 9 wherein trivalent chromium ions are present in an amount from 0.05 g/l up to saturation.					
	6. An aqueous acidic peroxide-free solution suitable for treating receptive metal substrates to impart a chromium passivate film thereon comprising chromium ions substantially all of which are present in the trivalent state, hydrogen ions to provide an acidic pH, nitrate ions as the essential oxidizing agent present in an amount sufficient to activate the hydrated trivalent chromium to form a chromate film on the substrate, and at least one additional metal ion selected from iron, cobalt, nickel, molybdenum, manganese, aluminium, lanthanum, cerium and lanthanide mixtures present in an amount effective to activate the formation of the chromate passivate film.					
40	7. A solution as claimed in Claim 6 in which the trivalent chromium ions are present in an amount of from 0.05 g/l up to saturation.					
	8. A solution as defined in Claim 5 or 6 in which the trivalent chromium ions are present in an amount of from 0.2 to 4 g/l.					
	9. A solution as claimed in Claim 5 or 6 in which the trivalent chromium ions are present in an amount of from 0.5 to 2 g/l.					
45	10. A solution as claimed in any one of Claims 1 to 9 having a pH of from 1.2 to 2.5.					
	11. A solution as claimed in any one of Claims 1 to 9 having a pH of from 1.5 to 1.8.					
	12. A solution as claimed in any one of claims 1 to 11 in which the nitrate ions are present in an amount of from 0.5 g/l up to saturation.					
50	13. A solution as claimed in any one of Claims 1 to 11, in which the nitrate ions are present in an amount of from 5 to 50 g/l.					
	14. A solution as claimed in any one of Claims 3, 4 and 6 to 13, in which the additional metal ion is present in an amount of from 0.02 to 1 g/l.					
	15. A solution as claimed in any one of Claims 3, 4 and 6 and 13, in which the additional metal ion is present in an amount of from 0.1 to 0.2 g/l.					
55	16. A solution as claimed in any one of Claims 1 to 15 including sulphate ions.					
	17. A solution as claimed in Claim 16, wherein the sulphate ions are present in an amount up to about 15 g/l.					
60						

18. A solution as claimed in Claim 16, wherein the sulphate ions are present in an amount of from 0.5 to 5 g/l. 5

19. A solution as claimed in any one of claims 1 to 18 including halide ions. 5

20. A solution as claimed in Claim 19, wherein the halide ions are present in an amount up to about 2 g/l. 5

21. A solution as claimed in Claim 19 in which the halide ions are present in an amount of from 0.1 to 0.5 g/l. 5

22. A solution as claimed in any one of Claims 1 to 21 including an organic carboxylic acid. 10

23. A solution as claimed in Claim 22, wherein the organic carboxylic acid is present in an amount up to 4 g/l. 10

10 24. A solution as claimed in any one of Claims 1 to 23 including a bath soluble and compatible silicate compound. 10

25. A solution as claimed in Claim 24, wherein the silicate compound is present in an amount up to about 5 g/l calculated as SiO_2 . 10

26. A solution as claimed in any one of claims 1 to 25 including at least one bath soluble and compatible 15 wetting agent. 15

27. A solution as claimed in Claim 26, wherein the wetting agent is present in an amount up to about 1 g/l. 15

28. A solution as claimed in Claim 26, wherein the wetting agent is present in an amount of from 50 to 100 mg/l. 20

29. A solution substantially as herein described with reference to any one of the Examples. 20

30. A process for treating a receptive metal substrate to impart a chromate passivate film thereon which comprises contacting the substrate with a solution as claimed in any one of Claims 1 to 29 at a temperature and for a period of time sufficient to form a passivate film thereon. 20

31. A process as claimed in Claim 30, wherein the temperature is kept within a range of from 40 to 150°F (4 to 66°C). 25

32. A process as claimed in Claim 30 wherein the temperature is kept within a range of from 70° to 90°F (21 to 32°C). 25

33. A process substantially as herein described with reference to any one of the Examples. 25

34. A substrate having a chromate passivate film imparted by means of a solution as claimed in any one 30 of claims 1 to 29 and/or by a process as claimed in any one of Claims 30 to 33. 30